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Influence of gluten–soy protein blends on the quality of reduced carbohydrates cookies ☆

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Abstract

The dietary requirements of consumers following low-carbohydrate diets are generating a market for protein-fortified products. Soy protein has been shown to lower cholesterol in hypercholesterolemic individuals, and it favorably affects calcium metabolism and kidney function relative to other high-quality proteins. The objective of this research was to investigate the incorporation of protein blends to reduce the carbohydrates on the acceptability and quality characteristics of cookies. Cookies were prepared using AACC method 10-53. Flour in the cookie formulation was replaced (10%, 15%, 20%, 25% and 30%) with the protein blend, increasing the protein content from 6% to 17.5% and reducing total carbohydrates. Water content was adjusted based on the measurements using the Farinograph water absorption. Water activity and hardness of cookies were not affected by the increasing flour replacement. The color of the cookies was darker as the protein blend increased beyond 20%. There is a definite potential for increasing the nutritional quality of cookies while reducing the carbohydrates.
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Keywords: Gluten; Soy protein isolates; Farinograph; Cookies; Fortify

1. Introduction

Coronary heart disease (CHD) is a major public health concern because it causes more deaths in the US than any other disease (American Heart Association, 2005). Risk factors for CHD include high total cholesterol levels and high levels of low-density lipoprotein (LDL) cholesterol. Obesity is believed to be an independent risk factor for CHD (Gensini, Comegilo, & Colella, 1998). Weight loss by means of restricting carbohydrates in the diet is one of the strategies adopted by many individuals. Grain-based products are traditionally higher in carbohydrates, so they are not consumed or are consumed in smaller quantities by those on such types of diets. Cookies, one of the most common snack food due to their general acceptability, convenience and shelf-life, are most affected by the trend. There is a need to produce low-carbohydrate cookies for this sector of consumers.

In order to lower the carbohydrates, increasing the protein is a sensible choice. Unlike animal protein, vegetable protein appears to be associated with a lower risk of CHD (Terpstra, Hermus, & West, 1983). This effect may be reflected by decrease in serum cholesterol concentrations (Manson et al., 1992). Soy protein is associated with significant decreases in serum cholesterol and LDL cholesterol concentrations (Anderson, Johnstone, & Cook-Newell, 1995). In 1999, the FDA authorized the use of health claims about the role of soy protein in reducing the risk of CHD on labeling of foods containing soy protein (FDA talk paper, 1999).

The concept of using composite flours is not new and has been the subject of numerous studies. Acceptable wheat products can be made with as much as 20–40% substitution by purified starches, 10–30% rice flour, 5–20% cereal and root flours or by 3–15% of proteinaceous flours (Fellers & Bean, 1988). Over the years, a number of studies

☆Names are necessary to report factually on available data; however, USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

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have been reported on high-protein cookies using soy flour (Tsen, Peters, Schafter, & Hoover, 1973), corn gluten meal and soy (Buck, Walker, & Watson, 1987), sunflower kernels (Bajaj, Kaur, & Sidhu, 1991), and pulse flours (Singh, Bajaj, Sharma, & Sidhu, 1993). Kaur, Kaur, and Sharma (1999) found that cookies made with 30% pigeon pea flour were acceptable. Bajaj et al. (1991) substituted 30% flour with wheat germ without affecting the acceptability. James, Courtney, and Lorenz (1989) found that cookies containing soy protein isolate (SPI) were acceptable in color, crispness and flavor. Claughton and Pearce (1989) found that sugar snap cookies containing up to 15% sunflower protein isolate were acceptable. The spread factor was reduced with the increase in the protein content in the cookies (Claughton & Pearce, 1989; Bajaj et al., 1991). The presence of high glutenin subunits per unit of flour was found to reflect negatively on the quality of cookies due to the effect of these units on the mixing properties of the dough (Hou, Yamamoto, & Ng, 1996). The quality of the wheat flour as represented by the gluten has a direct effect on the dough mixing properties. Gaines, Kassuba, and Finney (1990) reported an increase in cookie hardness with increased mixing time. It is well established that soft wheat flour performs better in high sugar products, such as cookies, due to the presence of weak gluten (Hoseney, 1989; Slade, Levine, & Finley, 1989). In the presence of 5% whey protein concentrate, cookies diameter was increased. The increase in the diameter is the result of interaction between whey protein and gluten. Protein content and quality implied by Farinograph can be used to predict the diameter of the cookies (Labuschagne, Coetzee, & Van Deventer, 1996).

Chen, Weingartner, and Brewer (2003) indicated that consumers are beginning to let go of the negative opinions they once held about soy-containing products. The objective of this study was to determine the effect of wheat gluten and soy protein blends with added water on sugar snap cookie quality. The earlier studies on the subject did not compensate for the need of additional water by the proteins.

2. Materials and methods

2.1. Protein blend

Protein blends were prepared using vital gluten (MGP Ingredients of Illinois) and SPIs (soy nuggets, NRG Foods). The soy nuggets were ground in a coffee grinder. Gluten and the ground SPI were blended in ratios of 70:30, 50:50, and 30:70. The gluten and SPI were placed in a large polyethylene bag and mixed thoroughly by hand.

2.2. Water absorption

A Brabender Farinograph-E was used to measure the water absorption for flour replaced with protein. Standard parameters (water absorption = 60%, 14% moisture, 500 FU consistency) according to the AACC method 54-21(AACC, 2000b) were followed using a 10 g mixing bowl. Tolerance index (MTI) (difference in BU from top of curve at peak to top of curve measured at 5 min after peak is reached) and Stability (difference, to closest 0.5 min, between point where the top of curve first intersects 500-BU line and point where top of curve leaves BU line) were derived from the Farinograph curves.

2.3. Baking

Wire-cut formula cookies were prepared using the AACC method 10-53 (AACC, 2000a). Each treatment was baked in three batches. Commercial pastry flour (Flaktex, Schaumburg, IL), superfine granulated sugar (C&H Sugar Co. Inc., Crockett, CA), brown sugar (Imperial Sugar Co., Sugar Land, TX), nonfat dry milk (Dairy America, Fresno, CA), sodium bicarbonate (Kroger Co., Cincinnati, OH), shortening (Crisco, The J.M. Smucker Co., Orrville, OH), and high-fructose corn syrup (Cargill, Eddyville, IA) were used in the formulation. Flour in the cookie formulation was replaced (10%, 15%, 20%, 25%, and 30%) with the prepared protein blend. Water was adjusted based on the results from the Farinograph water absorption, presented in Table 1. The cookie dough was mixed in a Kitchen Aid mixer (St. Joseph, MI) equipped with a paddle beater. The cookies were baked at 205 °C in an oven (National Mfg. Co., Lincoln, NE) for 11 min. Cookies were stored in plastic bags with zipper-type closure for 24 h after cooling until analysis.

2.4. Cookie geometry

Cookie width (W) and stack height (T) of eight cookies were measured according to AACC method 10-53 (AACC, 2000a). The spread factor was calculated as W/T.

2.5. Color evaluation

Color differences in the cookies were determined using the LabscanXE Hunter colorimeter (Hunter Associates Laboratories Inc., Reston, VA, USA), using the Universal software version 4.01. The CIElabv 10°/C scale was used to obtain the values for L (lightness scale 100 = pure white, 0 = black), a* (red) and b *(yellow). The hue angle ($\tan^{-1}(b^*/a^*)$) and chroma or intensity ($(a^{*2}+b^{*2})^{-2}$) of cookies were calculated. The top and the bottom surfaces of the cookies were used for the color measurement. Three measurements per cookie were taken and reported as an average.

2.6. Texture evaluation

Three cookies were evaluated measuring the peak breaking force (g) using the three-point break (triple beam snap) technique with the TA XT2i Texture Analyzer (Texture Technologies Corporation, Scarsdale, NY,

Table 1
Amounts of wheat flour, gluten, and SPI used in the cookie formulations

Gluten:SPI blend	Flour replacement (%)	Flour (g)	Gluten (g)	SPI (g)	Water (ml)
70:30	0	227.6	0.0	0.0	46.9
	10	204.8	15.9	6.8	51.7
	15	193.5	23.9	10.2	54.4
	20	182.1	31.9	13.7	57.9
	25	170.7	39.8	17.1	61.5
	30	159.3	47.8	20.5	63.2
50:50	0	227.6	0.0	0.0	46.9
	10	204.8	11.4	11.4	51.3
	15	193.5	17.1	17.1	54
	20	182.1	22.8	22.8	57.9
	25	170.7	28.5	28.5	61
	30	159.3	34.1	34.1	64.6
30:70	0	227.6	0.0	0.0	46.9
	10	204.8	6.8	15.9	51.3
	15	193.5	10.2	23.9	54.8
	20	182.1	13.7	31.9	57.5
	25	170.7	17.1	39.8	60.2
	30	159.3	20.5	47.8	64.6

USA). The analyzer was set to return to start cycle, a speed of 1 mm/s and a distance of 10 mm. A force–time diagram was taken for each test. The force-time plots were analysed for peak breaking force (g) and the time (s) to reach the peak. All measurements were conducted three times and the presented values are mean values.

2.7. Moisture and water activity

Moisture of the cookies was measured using the HG53 Halogen Moisture Analyzer (Mettler Toledo) set at 120 °C for 20 min. Water activity was measured in Aqualb 3TE (Decagon Device, Inc., Pullman, WA, USA). The cookie was crushed and a representative part of it used for testing. The average of the measurement of two cookies was used.

2.8. Protein

The protein content ($N \times 6.25$) of the cookies and blends was determined by nitrogen combustion analysis using the LECO FP-528 Protein/Nitrogen Determinator (Leco Corporation, St. Joseph, MI). The protein content of the cookies was reported using percent as-is basis.

2.9. Statistical analysis

Data were evaluated by analysis of variance (ANOVA), general linear models, and correlation analysis procedures of the Statistical Analysis System, version 8.02 (SAS Institute Inc., Cary, NC, USA). Means were compared using the Duncan test at the 0.05 level of probability.

3. Results and discussion

Farinograph water absorption plots (Fig. 1) show the comparison of the control (100% wheat flour) and a 20% substitution with 70:30 gluten SPI blend. MTI was lower as the protein blends percentage in the cookies blend increased (Fig. 2). It is noticeable that higher amount of SPI in the blend increased the MTI, i.e., reduced stability. The Farinograph stability increased as the ratio of the gluten–SPI blends increased in composite flours (Fig. 3). Gluten development for the composite flour with higher amount of gluten SPI blends was faster, and the resistance to over- and under-mixing was higher. High gluten strength will produce hard cookies with very low spread, while soft gluten yields thin cookies (Slade et al., 1989). The blends used in this work, after a number of tries, were determined based on the Farinograph mixing properties of the selected blends. Finney and Bains (1999) reported correlation between Farinograph mixing profile of wheat flour and cookie diameter. The flour replacement with the protein blend resulted in higher water absorption (Fig. 4). There was a significant ($P<0.0001$) correlation ($r = 0.92$) between the protein content of the cookies and the water absorption. The results were in accordance to McWatters (1978) who observed drier and crumbly dough with 20% and 30% replacement of wheat flour with only soybean flour. MacRitchie (1984) also reported the greater the protein content, the more the water absorbed.

3.1. Protein content

The protein content of the blends varied between 78.8 and 83.3, the 30:70 (Gluten:SPI) blend having the highest protein and the 70:30 blend the least. The protein content

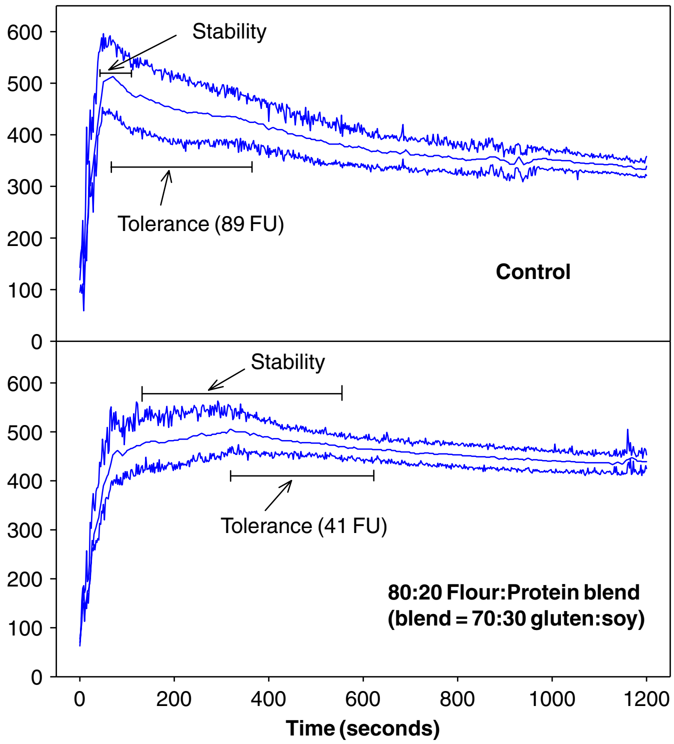

Fig. 1. Farinograms for 100% flour and 80:20 flour:protein blend.

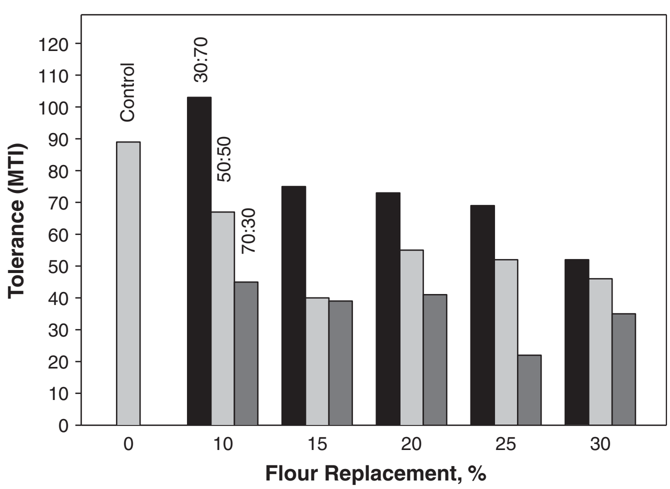

Fig. 2. Effect of gluten–SPI blends, and its amounts on the mixing tolerance index of flour.

of the cookies increased with the increase in the amount of the blends. The results are reported as Fig. 5. The protein content of the cookies baked with composite flour having higher amount of protein blends was higher than those with flour. This was expected, as flour with 9.8% protein was replaced with high-protein blends. Proteins used to prepare the blends (gluten and SPI) are contaminated with other components, i.e., carbohydrates, lipids, and ash. The increase in protein content indicated a corresponding decrease in the carbohydrate content of the cookies with increasing replacement of flour.

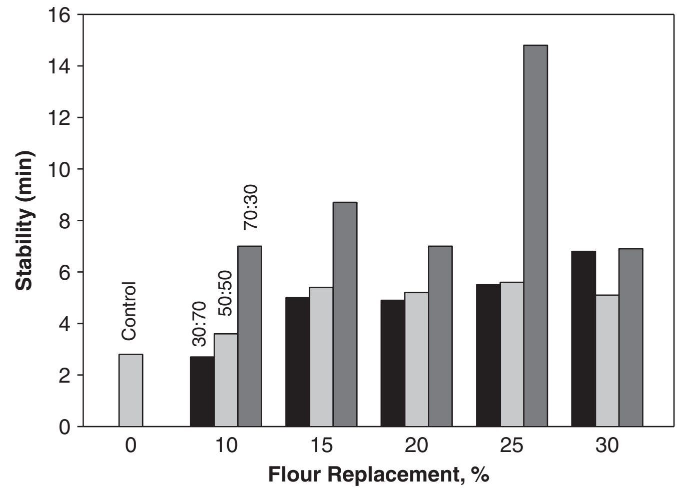

Fig. 3. Effect of gluten–SPI blends, and its amounts on the stability of flour.

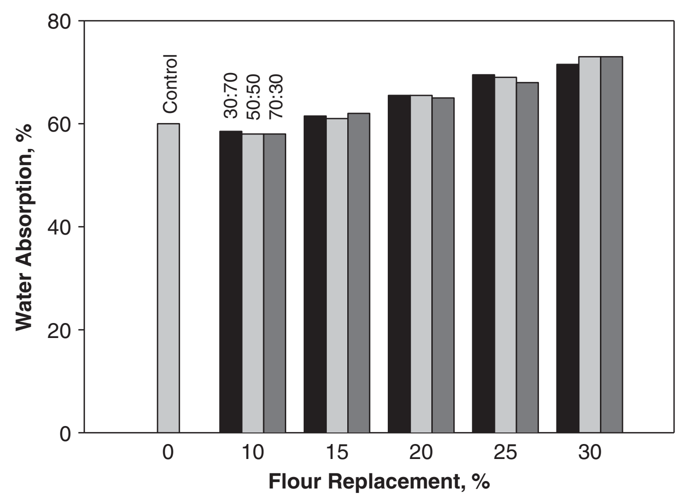

Fig. 4. Effect of levels of flour replacement with gluten–SPI protein blends on the water absorption.

3.2. Cookie geometry

The diameter of the cookies was negatively correlated to the protein content of the cookies. The addition of up to 15% of the blends did not significantly affect the width of the cookies, but additional increases in the amount of protein added decreased the width significantly. However, the blends were not significantly different from each other in respect to the diameter of the cookies. The magnitude of cookie diameter reduction due to the blends addition was dependent on the amount of gluten in the blend. High gluten content in the protein blend resulted in smaller cookie spread. The 10% addition did not significantly affect the height of the cookies, but 15% and above replacement resulted in cookies with more height. Protein content significantly affected the diameter and the thickness of the cookies (Table 2), possibly by retaining more air

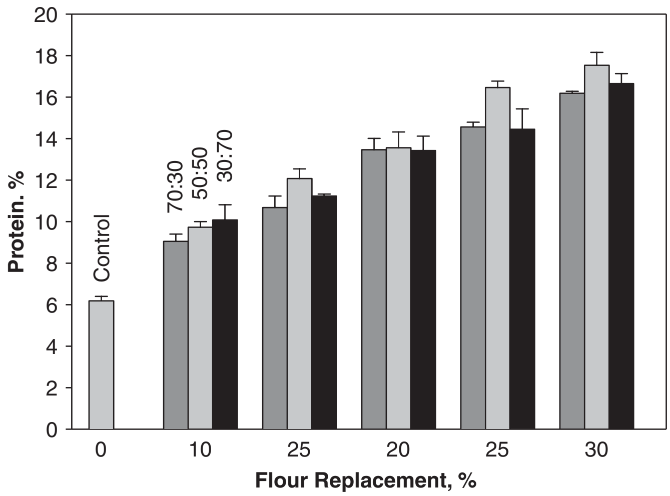

Fig. 5. Effect of flour replacement on the final protein content of the cookies.

Table 2
Effect of flour replacement on the cookie geometry

Gluten:SPI blend	Flour replacement (%)	Width (W) (cm)	Height (T) (cm)	W/T
70:30	0	64.13^{a}	7.73^{c}	8.29^{a}
	10	63.43^{b*}	7.70^{c}	8.26^{a}
	15	63.24^{b*}	7.83^{c}	8.09^{a}
	20	63.00^{b*}	7.86^{c}	8.03^{a}
	25	61.68^{c*}	8.33^{a*}	7.61^{b*}
	30	61.52^{c*}	8.08^{b*}	7.41^{b*}
50:50	0	64.13^{a}	7.73^{c}	8.29^{a}
	10	63.83^{ab}	7.73^{c}	8.26^{a}
	15	64.01^{ab}	7.79^{bc}	8.24a
	20	63.47^{b*}	7.87^{b*}	8.08^{b*}
	25	62.86^{c*}	7.89^{b*}	7.98^{b*}
	30	62.04^{d*}	8.11^{a*}	7.66^{c*}
30:70	0	64.13^{a}	7.73^{c}	8.29^{a}
	10	63.73^{ab}	7.76^{bc}	8.23^{ab}
	15	63.71^{ab}	7.87^{b*}	8.11^{b*}
	20	62.98^{bc*}	7.84^{bc}	8.07^{b*}
	25	62.81^{c*}	8.12^{a*}	7.71^{c*}
	30	62.99^{bc*}	8.12^{a*}	7.68^{c*}

Data are mean value of three replicates.
Means for the same blend and variable with unlike superscripts indicate significant differences using Duncan's multiple range test ($P<0.05$).
*Denotes significant differences from control ($P<0.05$).

produced during mixing due to faster gluten development. The blends were not different from each other, but had greater height than the control. The cookies had a lower spread factor as the flour replacement was increased. This was in agreement with the earlier studies reported by McWatters (1978) and Singh et al. (1993), who also reported a decrease in spread factor with increased protein in the cookies.

It is well established that soft wheat flour performs better in high sugar products, such as cookies, due to the presence of weak gluten (Hoseney, 1989; Slade et al., 1989). In the presence of 5% whey protein concentrate, cookies diameter was increased. The increase in the diameter is the result of interaction between whey protein and gluten (Kadharmestan, Baik, & Czuchajowska, 1998).

3.3. Moisture and water activity

The blends did not have a significant effect on the moisture content of the cookies relative to the control (Table 3). The amounts of protein blends were not significantly different from the control, though there was variation among the different levels of the blends substituted for flour.

The water activity, an indicator for the keeping quality of the cookies, was not affected either by the protein blend or by the amount of blend added to replace the flour (Table 3). This is because the water content in the formula was adjusted to the requirements of the composite flours based on the Farinograph water absorption data.

3.4. Texture

The effect of flour replacement on the textural properties of the cookies is presented in Table 4. The maximum peak force required to snap the cookies did not vary among the blends. All blends required force similar to that for the control cookies. The amount of the blend used to replace

Table 3
Effect of flour replacement on the moisture and water activity of the cookies

Gluten:SPI blend	Flour replacement (%)	Moisture (%)	a_w
70:30	0	4.89^{a}	0.33^{a}
	10	4.70^{ab}	0.29^{a}
	15	4.51^{b*}	0.32^{a}
	20	4.77^{ab}	0.33^{a}
	25	4.97^{a}	0.36^{a}
	30	4.93^{a}	0.24^{a}
50:50	0	4.89^{b}	0.33^{ab}
	10	4.35^{d*}	0.31^{b}
	15	4.57^{c*}	0.32^{b}
	20	4.87^{b}	0.34^{ab}
	25	4.62^{c*}	0.32^{ab}
	30	5.04^{a*}	0.35^{a}
30:70	0	4.89^{ab}	0.33^{b}
	10	4.09^{d*}	0.33^{b}
	15	4.34^{cd*}	0.32^{b}
	20	4.56^{bc}	0.34^{b}
	25	4.99^{a}	0.38^{a*}
	30	5.12^{a}	0.35^{ab}

Data are mean value of three replicates.
Means for the same blend and variable with unlike superscripts indicate significant differences using multiple range test ($P<0.05$).
*Denotes significant differences from control ($P<0.05$).

flour in the cookies did not significantly affect the texture of the cookies, as evidenced by the peak force required to break the cookies. This was in contradiction to earlier studies that have reported an effect of protein on the breaking strength of the cookies. Dreher and Patek (1984) observed a trend toward decreasing breaking strength with increasing high-protein bean flours. The key difference between the two systems was that they used bean flour, and in this work, protein was used. McWatters, Ouedraogo, Resurreccion, Hung, and Phillips (2003) attributed the harder texture of the cookies to the increased protein content and its interaction during dough development and baking. The data in Table 4 showed a trend of increase in cookies hardness as the amount gluten increased in the blend. Maache-Rezzoug, Bouvier, Allaf, and Patras (1998) observed that the higher the percentage of protein, the lower the dough hydration; also the doughs lacked consistency and were crumbly. Composite flours form aggregates with increased number of hydrophilic sites available to compete for the limited free water in a cookie dough (Kissell & Yamazaki, 1975). Increasing the water content proportional to their water absorption could ease the competition and result in sufficient mixing of the doughs.

Table 4
Effect of flour replacement on the texture of the cookies

Gluten:SPI blend	Flour replacement (%)	Force (g)	
		Mean	St. dev
70:30	0	1682.00^{ab}	*330.79*
	10	1400.4^{b}	*422.90*
	15	1580.2^{ab}	*490.57*
	20	1760^{ab}	*328.76*
	25	1877.3^{a}	*462.07*
	30	1915.3^{a}	*337.16*
50:50	0	1682.00^{ab}	*330.79*
	10	1590.97^{ab}	*295.93*
	15	1428.22^{b}	*353.91*
	20	1563.92^{b}	*224.46*
	25	1514.54^{b}	*245.41*
	30	1901.72^{a}	*81.51*
30:70	0	1682.00^{a}	*330.79*
	10	1399.20^{a}	*509.70*
	15	1303.63^{a}	*490.57*
	20	1382.07^{a}	*119.94*
	25	1664.72^{a}	*294.62*
	30	1630.23^{a}	*364.07*

Data are mean value of three replicates.
Means for the same blend and variable with unlike superscripts indicate significant differences using Duncan's multiple range test ($P<0.05$).
*Denotes significant differences from control ($P<0.05$).

3.5. Color

The top surface color of the cookies was influenced both by the amount and the type of the flour replacement (Table 5). Cookies made with higher SPI in the blends (30:70 gluten–SPI) were darker (lower L* value) than the cookies with lower SPI (70:30 gluten–SPI), which was darker than the control (0% SPI). The blends with 30% and 50% SPI were not significantly different in the top L* value, but were significantly darker than the cookies made

Table 5
Effect of flour replacement of the top surface color of the cookies

Gluten:SPI blend	Flour replacement (%)	L*	a*	b*	Chroma	Hue angle
70:30	0	66.3^{a}	9.0^{e}	33.1^{e}	34.3^{e}	74.7^{a}
	10	65.3^{c*}	9.9^{c*}	34.5^{d*}	35.9^{d*}	74.0^{cd*}
	15	66.1^{b*}	11.3^{d*}	34.4^{d*}	35.7d*	74.5^{b*}
	20	65.3^{c*}	10.2^{b*}	35.1^{c*}	36.6^{c*}	73.8^{d*}
	25	65.8^{b*}	10.1^{bc*}	35.5^{b*}	36.9^{b*}	74.2^{c*}
	30	64.0^{d*}	11.2^{a*}	36.6^{a*}	38.3^{a*}	73.0^{e*}
50:50	0	66.3^{b}	9.0^{f}	33.1^{f}	34.3^{f}	74.7^{b}
	10	64.2^{c*}	11.0^{c*}	35.6^{d*}	37.3^{d*}	72.8^{d*}
	15	66.2^{a*}	10.0^{e*}	35.4^{e*}	36.8^{e*}	74.1^{a*}
	20	66.3^{a*}	10.3^{d*}	36.3^{c*}	37.7^{c*}	74.2^{a*}
	25	64.9^{b}	11.2^{b*}	37.2^{b*}	38.8^{b*}	73.3^{c*}
	30	64.3^{c*}	11.9^{a*}	37.9^{a*}	39.7^{a*}	72.6^{e*}
30:70	0	66.3^{a}	9.0^{d}	33.1^{f}	34.3^{f}	74.7^{a}
	10	65.6^{b*}	10.3^{c*}	34.7^{e*}	36.2^{e*}	73.5^{b*}
	15	64.8^{cd*}	11.3^{b*}	36.0^{d*}	37.7^{d*}	72.6^{c*}
	20	64.9^{c*}	11.4^{b*}	36.7^{c*}	38.4^{c*}	72.7^{c*}
	25	64.8^{cd*}	11.8^{a*}	37.6^{b*}	39.4^{b*}	72.5^{c*}
	30	64.5^{d*}	11.9^{a*}	38.1^{a*}	39.9^{a*}	72.7^{c*}

Data are mean value of three replicates.
Means for the same blend and variable with superscripts indicate significant differences using Duncan's multiple range test ($P<0.05$).
*Denotes significant differences from control ($P<0.05$).

Table 6
Effect of flour replacement of the bottom surface color of the cookies

Gluten:SPI blend	Flour replacement (%)	L*	a*	b*	Chroma	Hue angle
70:30	0	50.0^{a}	14.7^{f}	34.2^{c}	37.3^{e}	66.8^{a}
	10	48.0^{bc*}	15.9^{e*}	34.3^{c}	37.9^{cd*}	65.1^{b*}
	15	48.8^{b*}	16.3^{d*}	35.2^{b*}	38.8^{b*}	65.1^{b*}
	20	45.5^{d*}	17.0^{c*}	33.5^{d*}	37.6^{de}	63.0^{d*}
	25	47.3^{c*}	17.6^{b*}	35.8^{a*}	39.9^{a*}	63.9^{c*}
	30	43.1^{e*}	18.3^{a*}	33.5^{d*}	38.3^{bc*}	61.3^{e*}
50:50	0	50.0^{a}	14.7^{f}	34.2^{d}	37.3^{cd}	66.8^{a}
	10	44.5^{c*}	16.5^{e*}	32.6^{cd}	36.5^{d}	63.2^{c*}
	15	47.4^{b*}	16.9^{d*}	35.1^{b*}	39.0^{b*}	64.2^{b*}
	20	48.2^{b*}	17.5^{c*}	36.3^{a*}	40.3^{a*}	64.2^{b*}
	25	42.9^{d*}	18.2^{b*}	33.2^{c*}	37.9^{c}	61.1^{d*}
	30	41.3^{e*}	18.4^{a*}	31.8^{d}	36.8^{d}	60.0^{e*}
30:70	0	50.0^{a}	14.7^{e}	34.2^{a}	37.3^{e}	66.8^{a}
	10	46.5^{b*}	16.6^{d*}	34.0^{a}	37.9^{b*}	64.0^{b*}
	15	45.6^{b*}	17.4^{c*}	34.0^{a}	38.2^{ab*}	62.9^{c*}
	20	45.2^{bc*}	18.0^{b*}	34.4^{a}	38.9^{a*}	62.4^{c*}
	25	44.0^{c*}	18.6^{a*}	34.2^{a}	38.9^{a*}	61.5^{d*}
	30	41.1^{d*}	18.7^{a*}	32.6^{b*}	37.5^{b*}	60.1^{e*}

Data are mean value of three replicates.
Means for the same blend and variable with unlike superscripts indicate significant differences using Duncan's multiple range test ($P<0.05$).
*Denotes significant differences from control ($P<0.05$).

without SPI. The blend with 70% SPI was significantly darker than the other blends.

The cookies made with 30% flour replacement were significantly darker than those with 25%, which were significantly darker than the control. The top surface color of the cookies had more red (a*) and yellow (b*) as the amount of SPI increased in the blend, and also when the amount of the flour replacement increased. The chroma of the top surface of the cookies made with blends containing increasing amounts of SPI increased significantly. Every increment in the amount of flour replacement resulted in cookies with significantly more intense top color. The hue angle, however, decreased with the increase in SPI in the blends, and with increasing flour replacement, was in the range of 72.5 to 74.7, indicating brown color.

The color of the bottom cookie surface followed a similar trend, as the lightness of the cookies increased with the increasing amount of the blend (Table 6). The chroma for the bottom surface of the cookies was significantly higher than that of the control samples. The hue angle decreased with the increase in SPI in the blend and with the increase in the amount of the blends. The replicates were not significantly different from each other.

4. Conclusions

The gluten–SPI blends used to replace up to 30% flour did not significantly affect the texture, moisture, and water activity of the cookies. This was in part due to the adjustment of water in the formulation based on the Farinograph water absorption. The color of the cookies was darker and the width to thickness ratio was lower as the flour was replaced with the high-protein blends. Low-carbohydrate cookies can be made by partially replacing the flour with gluten and SPI protein blends without adversely affecting the texture and the keeping quality.

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References

American Association of Cereal Chemists (AACC). (2000a). Approved methods of the AACC, 10th ed. Method 10-53. St. Paul, MN: The Association.

American Association of Cereal Chemists (AACC). (2000b). Approved methods of the AACC, 10th ed. Method 54-21. St. Paul, MN: The Association.

American Heart Association. (2005). *Heart disease and stroke statistics—2005 Update*. Dallas, TX: American Heart Association.

Anderson, J. W., Johnstone, B. M., & Cook-Newell, M. E. (1995). Meta-analysis of the effects of soy protein intake on serum lipids. *New England Journal of Medicine*, *333*(5), 276–282.

Bajaj, M., Kaur, A., & Sidhu, J. S. (1991). Studies on the development of nutritious cookies utilizing sunflower kernels and wheat germ. *Plant Food for Human Nutrition*, *41*, 381–387.

Buck, J. S., Walker, C. E., & Watson, K. S. (1987). Incorporation of corn gluten meal and soy into various cereal-based foods and resulting product functional, sensory and protein quality. *Cereal Chemistry*, *64*, 264–269.

Chen, D. J., Weingartner, K., & Brewer, M. S. (2003). Consumer evaluation of soy ingredient-containing cookies. *Journal Food Quality*, *26*, 219–229.

Claughton, S. M., & Pearce, R. J. (1989). Protein enrichment of sugar-snap cookies with sunflower protein isolate. *Journal of Food Science*, *54*, 354.

Dreher, M. L., & Patek, J. M. (1984). Effects of supplementation of shortbread cookies with roasted whole bean flour and high protein flour. *Journal of Food Science*, *49*, 922–924.

FDA talk paper. (1999). FDA approves new health claim for soy protein and coronary heart disease. US Food and Drug Administration Web site. Available at: http://vm.cfsan.fda.gov:80/~lrd/tpsoypr2.html. Accessed November 08, 2004.

Fellers, D. A., & Bean, M. M. (1988). Composite flours. *Food Reviews International*, *4*, 213.

Finney, P. L., & Bains, G. S. (1999). Protein functionality differences in eastern US soft wheat cultivars and interrelation with end-use quality tests. *Food Science and Technology*, *32*, 406–415.

Gaines, C. S., Kassuba, A., & Finney, P. L. (1990). Influence of chemical and physical modification of soft wheat protein on sugar-snap cookie dough consistency, cookie size, and hardness. *Cereal Chemistry*, *67*, 73–77.

Gensini, G. F., Comegilo, M., & Colella, A. (1998). *European Heart Journal*, *19*(Feb Suppl. A), 53–61.

Hoseney, R. C. (1989). The interactions that produce unique products from wheat flour. In Y. Pomeranz (Ed.), *Wheat is unique* (pp. 595–606). St. Paul, MN: American Association of Cereal Chemistry.

Hou, G., Yamamoto, H., & Ng, P. K. W. (1996). Relationships of quality of glutenin subunits of selected US soft wheat flours to rheological and baking properties. *Cereal Chemistry*, *73*, 358–363.

James, C., Courtney, D. L. D., & Lorenz, K. (1989). Rice bran-soy blends as protein supplements in cookies. *International Journal of Food Science and Technology*, *24*, 495–502.

Kadharmestan, C., Baik, B.-K., & Czuchajowska, Z. (1998). Whey protein concentrate treated with heat or high hydrostatic pressure in wheat-based products. *Cereal Chemistry*, *75*(5), 762–766.

Kaur, H., Kaur, B., & Sharma, S. (1999). Studies on the baking properties of wheat: pigeon pea flour blends. *Plant Food for Human Nutrition*, *54*, 217–226.

Kissell, L. T., & Yamazaki, W. T. (1975). Protein enrichment of cookie flours with wheat gluten and soy flour derivatives. *Cereal Chemistry*, *52*, 638–649.

Labuschagne, M. T., Coetzee, M. C. B., & Van Deventer, C. S. (1996). Biscuit-making quality prediction using heritability estimates and correlations. *Journal of the Science of Food and Agriculture*, *70*, 25–28.

Maache-Rezzoug, Z., Bouvier, J. M., Allaf, K., & Patras, C. (1998). Effect of principal ingredients on rheological behaviour of biscuit dough and on quality of biscuits. *Journal of Food Engineering*, *35*, 23–42.

MacRitchie, F. (1984). Baking quality of wheat flour. *Advances in Food Nutrition Research*, *3*, 207.

Manson, J. E., Tosteson, H., Ridker, P. M., Satterfield, S., Hebert, P., O'Connor, G. T., Buring, J. E., & Hennekens, C. H. (1992). Medical progress: The primary prevention of myocardial infarction. *New England Journal of Medicine*, *326*(21), 1406–1416.

McWatters, K. H. (1978). Cookie baking properties of defatted peanut, soybean, and field pea flours. *Cereal Chemistry*, *55*, 853–863.

McWatters, K. H., Ouedraogo, J. B., Resurreccion, V. A., Hung, Y. C., & Phillips, R. D. (2003). Physical and sensory characteristics of sugar cookies containing a mixture of fonio (Digitaria exilis) and cowpea (Vigina unguiculata) flours. *International Journal of Food Science and Technology*, *38*, 403–410.

Singh, B., Bajaj, M., Sharma, S., & Sidhu, J. S. (1993). Studies on the development of high-protein biscuits from composite flours. *Plant Food for Human Nutrition*, *43*, 181–189.

Slade, L., Levine, H., & Finley, J. W. (1989). In R. D. Phillips, & J. W. Finley (Eds.), *Protein quality and the effects of processing* (pp. 9–124). New York: Marcel Dekker.

Terpstra, A. H., Hermus, R. J., & West, C. E. (1983). The role of dietary protein in cholestrol metabolism. *World Review of Nutrition and Dietetics*, *42*, 1–55.

Tsen, C. C., Peters, E. M., Schafter, T., & Hoover, W. J. (1973). High protein cookies. Effect of soy fortification and surfactants. *Baker's Digest*, *47*, 34–39.